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OLED Revolution

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Abstract: This paper presents the concept of organic light emitting diode (OLED) as a modern trend in opto-electronic devices. OLED display technologies make it possible to get significant improvement in the bright light output, image resolution and the pixel response time with low operating voltages. These extremely thin devices consist of layers of organic molecules which emit light with application of electric current. The self-luminous devices made from OLEDs eliminate the need of backlight unlike Liquid Crystal Display (LCD) display. With recent development in manufacturing techniques, reduced costs are a remarkable factor. These all features increase worldwide adaptability and popularity of OLED.

Keywords: OLED, Electroluminescent, Liquid Crystal Display (LCD), AMOLED, PMOLED

I. INTRODUCTION

Organic Light emitting Diodes are simply films of organic polymers and small molecule substances, stacked together to make up an electroluminescent layer. The stack size of an OLED is less than 1µm. It has a self-luminous property which eliminates the need of a back light that is used in conventional LCDs. This results in very high resolution brighter displays with extremely thin and compact structure. OLEDs give a very wide dynamic colour range with high contrast ratio. Colour and brightness depends on the nature of organic materials used along with the current supplied.

II. STRUCTURAL ASPECTS

OLED components differ according to the number of organic layers present. A simple OLED can be made up of six different layers. Top and bottom layers are made of protective glass and plastic. These layers are called the seal and substrate. Two electrodes namely, electrode and counter electrode are placed between the specific layers. Light producing emissive and conductive layers are made from organic molecules and are placed between cathode and anode. As the number of layers increase the efficiency of the device also increases [1][7].

1) Anode: It is one terminal of an OLED which is kept at positive potential and is generally made up of Indium Tin Oxide (ITO). It facilitates injection of holes into the HOMO level of organic material and also shows transparency to visible light [2][8].

2) Cathode: This terminal end of OLED is kept at negative potential. Depending upon the type of OLED thin films of metals such as aluminium, barium and calcium are generally used. Transparent cathodes can be also used.

3) Emissive layer: It is made of organic plastic molecules. This layer is emissive as it radiates light in form of photons due to decay of the excited state of an electron and a hole. The wavelength of radiation emitted is in visible region and totally depends on the band gap energy. Polyfluorene is the commonly used emissive layer material.

4) Electron Transport layer (ETL): This layer helps electrons for their motion from one molecule to other. Tries (8-hydroxyquinolinato) aluminium i.e. Alq_3, TPBI and PBD are the materials generally used.

5) Holes transport layer (HTL): This layer facilitates motion of holes from molecule to molecule. TPD and NPB are commonly used components.

6) Substrate, Sink: They are supporting materials of an OLED and are made up of plastic, foil or even glass.

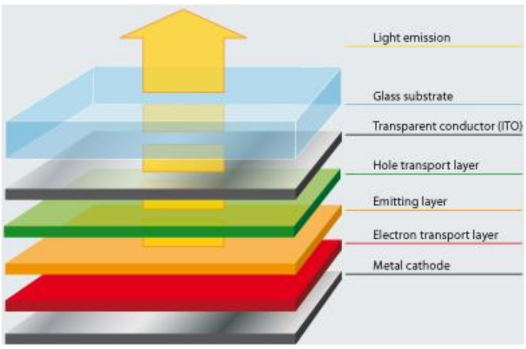

Fig. 1 Structure of an OLED [3]

III. WORKING PRINCIPLE

Delocalisation of Pi electrons makes organic molecules electrically conductive. The conductivity levels of these materials range from conductors to insulators thus making them organic semiconductors. The highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbitals (LUMO) of organic semiconductors are analogous to the valence and conduction bands of inorganic semiconductors [4] [10].

Low voltages from 2.5V to 20 V are applied to electrodes which produce very high electric fields within the range of 105 – 107 V/cm due to very thin active layers of10Å to

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100 nanometres. These high fields, near to breakdown electric fields support injection of charges across the electrode and active layers' interfaces. Holes and electrons are injected from the transparent anode and cathode respectively. Positive holes have more mobility than negative electrons. So they jump across the boundary from the conductive layer to the emissive layer [5][9]. When a hole and an electron combine, it results into an exciton, a bound state of the electron and hole. The exciton decays and releases a burst of energy in the form of a photon whose wavelength is in the visible region. This process is called recombination. This recombination happens many times a second which results in continuous light emission from the OLED as long as the current keeps flowing. The phenomenon is depicted in Figure 2.

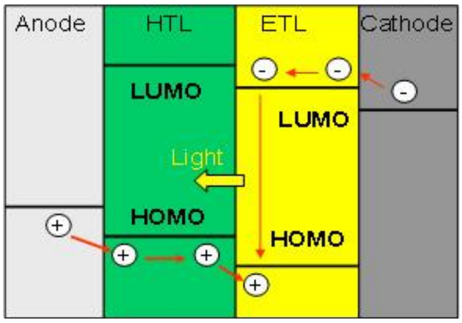

Fig. 2. Working of an OLED [6]

IV. TYPES OF OLEDS

A. Passive Matrix OLEDs (PMOLEDs)
PMOLEDs contain organic layers and strips of anode arranged perpendicular to the strips of cathode as shown in figure 3. These intersections make up a pixel where light gets emitted. External circuitry determines the strips of anodes and cathodes to which the current gets applied and thus in turn determines which pixel shall remain ON or OFF. The applied current determines the brightness of the pixel. PMOLEDs are expensive and consume more power as compared to other OLEDs. The PMOLED displays are restricted in their resolution and the size up to 2'' to 3'' and thus are efficient for smaller screens.

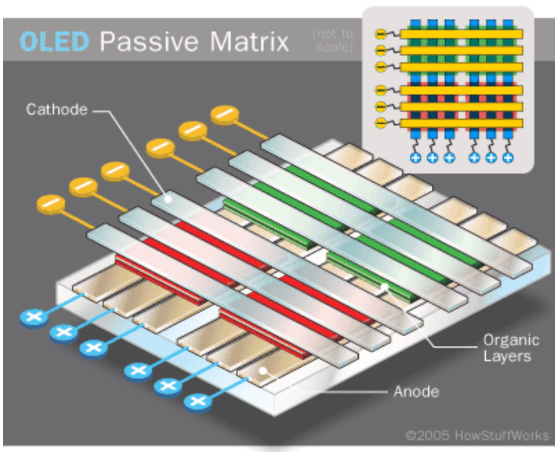

Fig. 3 PMOLED [5]

B. Active Matrix OLEDs (AMOLEDs)
AMOLEDs contain full layers of anode, cathode and organic molecules as shown in figure 4 [1][7]. To form a matrix, anode layers possess a thin film of transistors (TFT) in parallel. By switching the pixels ON or OFF, the desired image can be obtained. AMOLED displays are the most power efficient displays as the pixels remain OFF when not in use. This results in formation of a black image on the screen. These displays have quick refresh rates making them suitable for multimedia use. They are used in large screen Televisions, computer monitors as well as mobile phone screens.

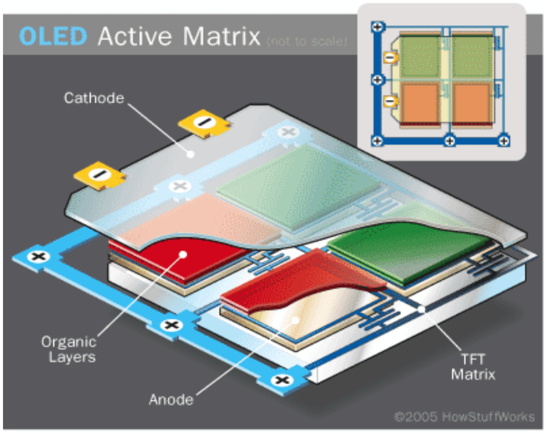

Fig. 4Working of an AMOLED [5]

C. Transparent OLEDs (TOLEDs)
The substrate, cathode and anode in TOLEDs are transparent in nature. Due to presence of transparent parameters on both sides, the displays emit from top as well as bottom. Such OLEDs are included in both active and passive matrixes. TOLEDs are used in heads-up display, mobile phones and laptops as they give good contrast even in bright sunlight.

D. Flexible OLEDs(FOLEDs)
FOLEDs are very flexible, light weight and durable as they have substrates made up of flexible metallic foils or plastics. Such displays are used in televisions, mobile phones and GPS devices as such devices are vulnerable to breaking. FOLEDS provide higher resolutions with high contrast images and a lower response time. This provides a more immersive experience for the users.

V. FABRICATION OF OLEDS

A. Organic vapour phase deposition (OVPD)
It is a low cost, efficient technique. In a low-pressure, hot-walled reactor chamber, a carrier gas transports evaporated organic molecules onto cooled substrates, where they condense into thin films [1][7]. The cost can be reduced and the efficiency can be increased by using a carrier gas.

B. Inkjet printing
It is the cheapest and most widely used technique. Inkjet technology is highly efficient which greatly reduces the

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cost of OLED manufacturing and allows OLEDs to be printed onto very large films for large displays, like big television screens and electronic billboards. Organic layers are sprayed onto substrates in the similar way a paper is printed.

C. Transfer-printing

It is an emerging technology with the capacity to manufacture large numbers of OLED and AMOLED devices. Transfer-printing takes advantage of standard metal deposition, photolithography, and etching to create alignment marks on device substrates, commonly glass [1][11]. To enhance resistance and improve surface defects thin polymer adhesive layers are applied. Backplane is coated with anode layer, over which OLED layers are formed using conventional deposition techniques. It is further covered with a metal electrode layer.

VI. SUPERIORITY OF OLED DISPLAY OVER LCD, LED DISPLAYS

1.) Due to thin light emitting layers, the substrate of OLEDs can be thinner, lighter and flexible.
2.) OLEDs are much brighter than LCDs and LEDs as the organic layers are much thinner than the inorganic crystals layers of LEDs. Due to glass some of the light emitted in LCDs and LEDs gets absorbed which is not the case with OLEDs.
3.) OLEDs do not require backlight as compared to LCDs that work by selectively blocking areas of back light to produce images. OLEDs consume very less power.
4.) OLEDs are mainly plastic so they can be produced into large, thin sheets.
5.) The response time of OLED displays is very high and so they can refresh very quickly. OLEDs respond 1000 times faster than LEDs.
6.) OLED pixel colour appears correct and without any shift even at angles of 90° or more.
7.) When OLED pixels are OFF, they provide the deepest black colour of any flat panel display.

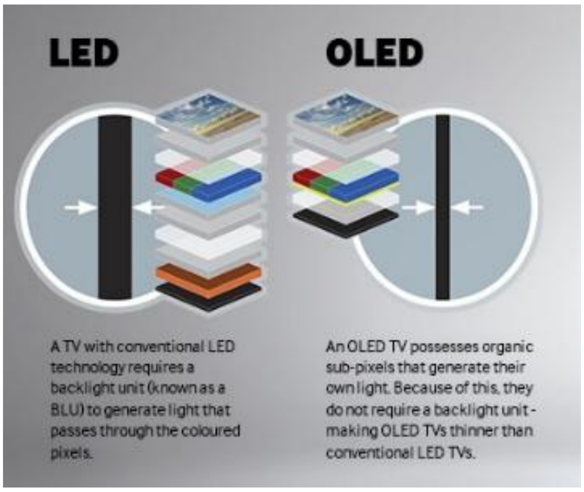

Fig. 5OLED vs LED [12]

VII. DRAWBACKS OF OLED DISPLAY

1.) Red and green OLEDs have longer lifetimes (46,000 and 2,30,000 hours respectively) as compared with blue OLEDs which have a life of just 1.6 years.
2.) Water can easily damage the displays
3.) The manufacturing processes for making OLEDs are costly.
4.) Varied lifespan of organic dyes causes a discrepancy between red, blue and green intensity. This may lead to image persistence known as burn in.
5.) Prolong exposure to UV rays damages the OLED displays.

VIII. FUTURE APPLICATIONS OF OLED DISPLAYS

OLEDs will soon be used in heads-up displays, automobile wind screens and dashboards, and billboard displays. Due to faster refresh rates OLEDs can be used in making devices used to exchange information in real time. FOLEDs and TOLEDs can be used in wearable electronic devices.

Fig. 6 Transparent laptop screen [13]

Fig. 6 LG Wallpaper TV screen [14]

OLED is now the most trustworthy technology of future as it promises to make viewing more convenient. By incorporating the advantages of light weight, slimmer, portable, eco-friendly and fashionable designs accompanied by good brightness and picture quality they are a key technology in development of flexible and transparent displays. With cheaper manufacturing techniques such displays would become omnipresent.

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Advancement in OLED technologies is a revolutionary field of research with very bright future.

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